Dec 4th, 12:00 AM

Review of Atrazine Water Monitoring Data in Iowa Relative to Label and Management Changes

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Abstract

Trends in atrazine detections and concentrations in Iowa surface and groundwater were reviewed relative to adoption of Best Management Practices and atrazine label changes designed to protect water resources. Analysis of a large statewide water monitoring database from 1982 to 1995 revealed statistically significant declines in both atrazine detection rates and concentrations in both groundwater and surface water. USGS monitoring of streams from 1989 to 1995 showed a decline in atrazine median concentration of almost 50%. Rural wells in Floyd and Mitchell Counties were sampled in 1986 and 1987 and resampled in 1994, four years after the area was designated as an atrazine management area. Mean atrazine concentrations declined by 87%, and no wells exceeded the atrazine Maximum Contaminant Level (MCL) drinking water standard (6% of wells exceeded the MCL in 1986). Other studies also documented declines in atrazine detections and concentrations, which have been attributed to improved management of the herbicide. Exposure of Iowans to atrazine through drinking water is low. For the period 1994-2002, eleven Community Water Systems (CWS) utilizing the most vulnerable surface water sources were intensively monitored for atrazine. Only one CWS in one year exceeded the 3 ppb annual average drinking water standard. In an analysis of all Safe Drinking Water compliance monitoring in Iowa for the period 1993 through 2000, no CWS utilizing groundwater had an atrazine detection of 3 ppb or greater. No atrazine was detected in 90.2% of groundwater.

Introduction

Detections of some pesticides in ground and surface water in the 1980s spurred changes in some pesticide labels and the adoption of voluntary Best Management Practices designed to reduce movement of pesticides to water. While these practices had been shown to be effective in small-scale studies, proof of their effectiveness on a wider scale awaited years of water quality monitoring sufficient to document downward trends in pesticide detections and concentrations. In this paper we report on the experience with the herbicide atrazine in Iowa, examining long-term water quality monitoring data relative to atrazine label changes and BMP adoption.

Atrazine was the most widely used corn herbicide in the U.S. and Iowa in the 1980s and remains the most widely used corn herbicide. Due to its widespread usage and physical properties, atrazine has been detected more frequently than other herbicides in the Corn Belt in surface and groundwater. Because of atrazine detections in water, the Iowa Department of Agriculture and Land Stewardship (IDALS) enacted one of the nation's first pesticide management plans in

December, 1989. Additionally, Ciba, the manufacturer of atrazine, made federal label changes in 1988, 1990, and again in 1993, designed to protect ground and surface water resources. Extensive educational efforts to improve handling and application of pesticides in general, and atrazine, specifically, were also conducted during this time period in Iowa. As these management changes designed to protect water resources have been in effect for almost a decade, and a number of water quality monitoring studies were ongoing during that period, long-term atrazine monitoring results were examined for evidence of declining trends in atrazine detections and concentrations.

Atrazine Label and Management Changes in Iowa

1988. A groundwater advisory statement was added to the federal label, cautioning against use where surface soils are coarse and groundwater shallow. Wording of the advisory was: "This product is a chemical which can travel (seep or leach) through the soil and can contaminate groundwater which may be used as drinking water. This product has been found in groundwater as a result of agricultural use. Users are advised not to apply this product where the water table (groundwater) is close to the surface and where soils are very permeable, i.e. well-drained soils such as loamy sands. Your local agricultural agencies can provide further information on the type of soil in your area and the location of groundwater."

1989. Iowa Secretary of Agriculture, Dale Cochran, signed administrative rules enacting the Iowa Atrazine Management Plan. Major components of the plan included:

1) Classification of atrazine as a Restricted Use Pesticide.
2) Reduction of maximum application rates statewide from 4 lb ac^{-1} to 3 lb ac^{-1}.
3) Mandate of annual reporting of atrazine sales by dealers.
4) Prohibition of application within 50 ft of sinkholes and wells.
5) Prohibition of mixing and loading within 100 ft of any well, cistern, sinkhole, streambed, lake, or impoundment.
6) Requirement that mixing, loading, and clean-out be conducted either with secondary containment or in the field.
7) Establishment of atrazine management areas where groundwater was highly vulnerable due to sinkholes, and/or agricultural drainage wells. In these areas, delineated at the township level in 23 counties, maximum atrazine rates were limited to 1.5 lb ac^{-1} (one half the allowed rate in the rest of the state).

1990. The federal label was changed to include many provisions similar to those enacted in Iowa, such as Restricted Use Classification, requirement of untreated setbacks around wells and sinkholes, and a maximum rate reduction.

1993. The federal label was changed to further address protection of surface water. The maximum rate (total per season) was reduced from 3 lb ac^{-1} to 2.5 lb ac^{-1}, with an additional rate restriction of 1.6 lb ac^{-1} on highly erodible land unless protective surface crop residue is present.

A 66 ft untreated setback was required at points of entry of surface runoff into streams. A 200 ft untreated setback was required adjacent to lakes and reservoirs.

In addition to regulatory changes, intensive educational efforts were carried out by Iowa State University Extension, Ciba, other herbicide manufacturers, and agricultural organizations. Many local and regional watershed protection programs were also active, such as the Southern Iowa Herbicide Education Program, a cooperative effort of the Iowa Natural Heritage Foundation, Iowa Fertilizer and Chemical Association, Regional Government, and herbicide manufacturers, begun in 1992.

Atrazine Trends in Iowa Groundwater

A number of monitoring studies are useful to track atrazine detection rates and concentrations over time. Each study is briefly summarized.

Iowa Groundwater Monitoring Program (IGWMP). Since 1982, untreated groundwater from Iowa municipal wells has been analyzed for the presence of selected pesticides. Using data from 89 wells which had been sampled repeatedly from 1982 to 1995, Kolpin, et al. (1997) analyzed for significant trends in pesticide concentrations using the Kruskal-Wallis test and a 95% confidence level. This analysis revealed a "substantive decrease in median atrazine concentration between the 1987 to 1991 and 1992 to 1995 time periods." About 80% of the wells where atrazine was detected had decreases in median atrazine concentrations. Alluvial wells showed the greatest decrease in atrazine concentrations. Changes in precipitation were ruled out as a potential cause of atrazine trends, the authors concluding, "There is no apparent relation between precipitation and the temporal patterns in median concentrations found for atrazine." Rather, the authors concluded that changes in management of atrazine (lower use rates, increased postemergence application, and state management plan restrictions) were causes of declining atrazine concentrations in wells.

Iowa Pesticide Water Resources Database (IAPEST). Initiated in 1991 by the Iowa Geological Survey Bureau (IGSB), this database was begun to aid IDALS in its development of a Generic State Pesticide Management Plan. A wide range of datasets from many sources is included in this database, with surface water data beginning in 1980 and groundwater beginning in 1982. Skopec and Hoyer (1998) recently analyzed this database for trends in pesticide detections from 1980-1995. The rate of detection (percent of samples with atrazine detected at any concentration) in groundwater declined from about 30% in 1982 to about 5% in 1995 (Figure 1). The authors performed a linear regression analysis to determine if upward or downward trends in herbicide levels were significant at the 95% confidence level. Wells were classified by groundwater region (such as bedrock, alluvial, and drift wells). Considering all 7 categories of groundwater, atrazine concentrations dropped significantly in 5 and remained the same in 2 (Table 1). Bedrock wells, which are best protected from and least affected by surface activities such as herbicide application to fields, showed one of the most substantial declines in atrazine concentrations. It is likely that efforts to divorce herbicide mixing and disposal practices from well sites has contributed to this improvement.

Table 1. Trends in atrazine concentrations for Iowa groundwater (1982-1995).

Groundwater Region	Linear Regression F-Statistics	Increase or Decrease
All Bedrock Wells	54.57**	Decrease
Alluvial Wells	18.29**	Decrease
Drift Wells	2.35	No change
Good Bedrock/Thin Cover	5.88**	Decrease
Good Bedrock/Moderate, Shale Cover	1.67	No change
Variable Bedrock/Thin Cover	21.26**	Decrease
Variable Bedrock/Moderate, Shale, & Thick Cover	378.14**	Decrease

** Significant at 0.05 level

Adapted from Skopec and Hoyer, Pesticide Trends in Surface and Groundwater in Iowa: 1980-1995, Iowa Dept. of Natural Resources.

Big Spring Study. Big Spring in Northeast Iowa is fed by a 103-sq. mi. watershed. Karst geology in the watershed is characterized by numerous sinkholes, which allow surface water to directly enter the shallow aquifer. Intensive sampling of Big Spring water for pesticides conducted by the IGSB began in 1982 and has continued since.

The flow-weighted mean concentration of atrazine was 0.31 ppb in 1982. When the flow-weighted mean concentration increased to 0.70 ppb in 1985, some observers speculated that this result signaled an inevitable further increase due to past activities. However, concentrations declined dramatically in the following three years to reach 0.13 ppb in 1988. This karst system responds rapidly to weather changes. Due to direct surface-to-groundwater connections through sinkholes, herbicide concentrations in spring effluent can change rapidly in a manner very similar to surface water. Heavy rainfall-runoff years in 1990 and 1991 increased atrazine concentrations to 1.06 and 1.17 ppb, respectively. However, very low atrazine concentrations of 0.27 or less were recorded the following four years, with the mean concentration in 1995 (the last year data has been reported) at an all-time low of 0.12 ppb (Liu, et al. 1997). This region was designated as an atrazine management area in 1989, and intensive educational efforts to improve atrazine management initiated.

Floyd and Mitchell County Well Study. In 1986 and 1987 IGSB and the University of Iowa Department of Preventative Medicine conducted a study of farm wells in Floyd and Mitchell Counties, a region with shallow bedrock, sinkholes, and ag drainage wells. This study produced valuable background data, as this area was later designated an atrazine management area in 1989. Atrazine was detected far more frequently in these vulnerable wells than in other Iowa studies. Folyd-Mitchell detection rates were as high as 72%, compared to a 4% detection rate in the State-Wide Rural Water-Well Survey discussed later.

Quade et al. (1994) resampled these wells in 1994, finding that both detection rates and concentrations of atrazine had declined. Atrazine was detected in 72% of wells in May 1986 and 64% of wells in May 1994. However, atrazine concentrations declined more dramatically from a mean concentration of 1.8 ppb in 1986 to 0.24 ppb in 1994 (an 87% decline). Maximum concentrations declined from 13.8 ppb to 1.1 ppb. In 1986, 6% of wells exceeded the 3 ppb

Maximum Contaminant Level (MCL) drinking water standard. In 1995, no wells exceeded the drinking water standard. Statistical analysis showed that these declines were highly significant. A comparison of water level and climate data did not show any significant change in climatic conditions between the two periods, which could have led to the decline in atrazine. Rather, the authors concluded that changes in management with the Atrazine Management Plan led to the improved well water quality.

It is important to consider the fact that usage of atrazine in these counties did not decrease during this time period. In fact, herbicide use surveys conducted in 1984 and 1994 showed that atrazine use actually increased, although the average rate per acre remained nearly constant at 1.5 lb ac^{-1} (Quade et al. 1994). Use of atrazine in tank mixes and package mixes (often at reduced rates) has increased in Iowa, explaining this trend. By changing how atrazine was mixed and loaded (divorcing such activities from wells) and applied (use of runoff-filtering setbacks adjacent to sinkholes) farmers were able to still gain the weed control and economic benefits of atrazine while providing better protection to their wells, and improving groundwater quality.

Statewide Rural Well Studies. The State-Wide Rural Well-Water Survey (SWRL) was a stratified, systematic sampling of water quality in randomly selected rural wells (Kross et al. 1990). Between April 1988 and June 1989, 686 private rural wells were sampled and analyzed for common pesticides. Atrazine was detected in 4% of wells (8% of wells had either an atrazine detect or atrazine metabolite detect). The maximum concentration detected was 6.61 ppb. Five wells contained atrazine at concentrations exceeding the 3 ppb MCL.

There has not been a complete resampling of SWRL wells. However, a similar, larger survey of rural wells was conducted in 1994 as a part of a 9-state study. Of the 819 Iowa rural wells studied, only one well contained atrazine at concentrations exceeding the 3 ppb MCL (as opposed to 5 in the smaller SWRL study). Contamination in that well was traced to a spill at the well site (personal communication Ken Choquette, Iowa Dept. of Public Health).

Atrazine Trends in Iowa Surface Water

Iowa Pesticide Water Resources Database (IAPESP). Skopec and Hoyer (1998) analyzed this previously described database for trends in pesticide detections in surface water from 1982-1995. Atrazine detection rates in surface water declined from over 90% in 1982 to slightly over 60% in 1995 (Figure 2). Linear regression analyses were performed to determine if trends in pesticide concentrations were significant at the 95% confidence level. Atrazine concentration trends were analyzed for all surface water and for 7 major interior river basins (Table 2). Atrazine concentrations decreased significantly for the all-surface water category (the largest decrease) and for 4 of the river basins. Concentrations in the remaining 3 basins remained unchanged.

Table 2. Trends in atrazine concentrations for Iowa surface water (1980-1995).

River Basins	Linear Regression F-Statistics	Increase or Decrease
All Surface Water	13.55**	Decrease
Northeastern Iowa Rivers	7.78**	Decrease
Cedar River	1.99	No change
Iowa River	0.07	No change
Skunk River	7.91**	Decrease
Des Moines River	1.15	No change
Southern Iowa Rivers	6.71**	Decrease
Western Iowa Rivers	9.91**	Decrease

** Significant at 0.05 level

Adapted from Skopec and Hoyer, Pesticide Trends in Surface and Groundwater in Iowa: 1980-1995, Iowa Dept. of Natural Resources.

U.S. Geological Survey (USGS) Midwestern Stream Monitoring. Atrazine levels in surface water have also declined more generally across the Corn Belt. Starting in 1989, the USGS began repeated monitoring of Midwestern streams for atrazine and other herbicides. Fifty-three sites were monitored in 9 states. Samples were taken in March or early April, prior to herbicide application, and during the first runoff event after herbicide application, when highest concentrations are expected. Ten sites in Iowa were included in the study. Sites were sampled in 1989 and 1990 and again in 1994 and 1995, to examine trends in herbicide concentrations. Post-application median atrazine concentrations (expected maximum concentrations) declined by almost 50% between 1989 and 1994 and 1995 (Goolsby et al. 1994; Goolsby et al. 1998). Analysis of data from sites in all 9 states also showed that atrazine concentrations had declined significantly between 1989/90 and 1994/95 (Battaglin and Goolsby 1999).

It is likely that reductions in atrazine concentrations in surface water have resulted from both specific actions related to atrazine (such as reduced rates, greater use of postemergence treatments which in turn reduce runoff, and use of untreated setbacks mandated by atrazine labels) and more general changes in farming practices. Conservation Compliance greatly speeded the adoption of conservation tillage and installation of grassed waterways and field borders, all of which reduce herbicide runoff.

Atrazine Exposure in Drinking Water.

Because atrazine has an MCL drinking water standard, public water supplies must regularly test for the chemical. Community Water Systems (CWS) must test for atrazine at least 4 times per year. If the annual average concentration of atrazine in finished water exceeds 3 ppb, water utilities must take steps to lower atrazine concentrations. In the past, a few public wells in Iowa have been contaminated by atrazine at levels above 3 ppb due to commercial mixing and disposal sites (Fawcett 1989). This cause of contamination was addressed with diking and containment regulations enacted by IDALS in 1985. Iowa was one of the first states in the nation to enact such regulations. Certain sites have been or are in the process of being remediated.

Recently, the only public drinking water sources which have approached or exceeded 3 ppb atrazine are certain surface water sources. Reservoirs are most vulnerable to exceeding the atrazine MCL on an annual basis, as spring runoff containing herbicides is stored for long periods, and atrazine degradation is slow under reservoir conditions.

Prior to atrazine management changes, there were examples of CWS surface water sources in Iowa which exceeded 3 ppb atrazine on an annual mean basis. However, atrazine concentrations in CWS source water have declined. Intensive, voluntary monitoring has been conducted at 11 Iowa CWS utilizing surface water reservoirs from 1994 through the present (Tierney et al. 2003). Raw and finished water have been sampled weekly from May through July (the period of highest runoff) and every-other-week for the remainder of the year. Results for finished water are shown in Table 3. The 9-year mean atrazine concentrations were less than 2 ppb for all CWS. From 1994 through 2002, there was only one example of a system exceeding 3 ppb atrazine in finished water on an annual basis. That system (Chariton) reported low atrazine concentrations the other 8 years of the study, averaging 0.88 ppb. Unlike many other systems, in 1998 when atrazine exceeded the MCL, this city did not have the capability to treat with activated carbon when runoff was heavy. Raw water also had relatively low atrazine concentrations, from a historical perspective (Table 4). For the years 1994 and 1997, none of the systems' raw water exceeded an average 3 ppb. In other years, from one to five systems exceeded 3 ppb in raw water.

Ten of the 11 surface water CWS reported having the option to treat water with activated carbon on an intermittent basis. Often this is done to reduce taste and odor problems. Some systems add carbon to reduce atrazine peaks after spring runoff. However, as the raw water analyses illustrate, most systems would not have to treat to meet drinking water standards.

Safe Drinking Water Act (SDWA) compliance monitoring data at Community Water Systems (CWS) in Iowa were obtained by Tierney et al. (2001) and linked to populations served by those CWS using a Population Linked Exposure (PLEX) database. Data on atrazine analyses were obtained from 993 CWS utilizing groundwater, 93 CWS utilizing surface water, and 29 CWS utilizing other water sources (such as blended groundwater and surface water) over the period January, 1993 through December, 2000. No atrazine was detected in 90.2% of groundwater, and 62.1% of other systems, with all surface systems having at least one atrazine detect. No groundwater or other systems had individual atrazine detects above the 3 ppb MCL, while 8.6% of surface water systems had point in time detects above 3 ppb.

Table 3. Finished Water Atrazine Annual and Period Means (1994-2002). For 11 Iowa CWS in the Voluntary Monitoring Program.

	Annual Means (ppb)									Mean period	Time period
CWS	1994	1995	1996	1997	1998	1999	2000	2001	2002	(ppb)	(years)
Fairfield[1]	0.26	0.38	0.74	0.49	0.72	0.05	0.05	0.05	0.05	0.31	9
Winterset[1]	0.96	0.16	0.20	0.39	0.22	0.36	0.77	0.57	0.44	0.45	9
Leon[1]	0.07	0.16	0.76	0.76	0.52	0.89	0.98	0.88	0.69	0.63	9
Rathbun[1]	1.55	0.85	1.61	0.73	0.37	0.36	0.34	0.54	0.59	0.77	9
Albia	1.07	0.28	1.52	1.28	1.17	1.1	--[2]	--[2]	--[2]	1.07	6
Osceola[1]	0.61	0.92	1.21	1.25	1.23	1.65	1.30	1.13	0.52	1.09	9
Lamoni[1]	1.77	0.63	2.19	0.61	0.99	0.85	0.49	0.95	1.36	1.09	9
Montezuma[1]	0.18	0.67	1.63	1.54	1.32	1.88	1.44	0.78	--[2]	1.18	8
Chariton	0.78	0.50	1.64	0.86	4.21	1.20	0.69	0.90	0.50	1.25	9
Centerville[1]	1.30	0.65	2.62	1.52	1.54	1.37	2.00	2.79	0.87	1.63	9
Mt. Ayr[1]	1.54	1.66	2.25	1.07	2.44	--[3]	1.08	1.99	--[2]	1.96	8

[1] Report activated carbon treatment process in place.

[2] CWS was not in the Voluntary Monitoring Program.

[3] Data insufficient to calculate an annual mean.

Table 4. Raw Water Atrazine Annual and Period Means (1994-2002). For 11 Iowa CWS in the Voluntary Monitoring Program

	Annual Mean (ppb)									Mean period	Time period
CWS	1994	1995	1996	1997	1998	1999	2000	2001	2002	(ppb)	(years)
Albia	1.07	0.28	1.52	1.28	1.17	1.10	--[3]	--[3]	--[3]	1.07	6
Fairfield[2]	0.37	1.67	1.94	0.91	1.96	1.20	1.62	0.34	--[5]	1.25	9
Lamoni[2]	--[4]	--[5]	2.44	0.58	2.74	--[5]	0.87	0.23	--[5]	1.37	9
Rathbun[2]	2.19	2.36	2.79	1.65	1.13	0.77	0.89	0.96	1.11	1.54	9
Montezuma[2]	0.26	1.79	2.42	1.80	1.97	2.42	2.02	1.27	--[3]	1.74	8
Leon[2]	0.66	0.70	2.73	1.88	1.65	2.18	2.32	2.05	2.08	1.81	9
Chariton	0.78[1]	0.50[1]	1.63[1]	0.86[1]	4.21[1]	1.20[1]	2.69	2.99	2.00	1.86	9
Winterset[2]	0.96[1]	2.93	1.88	1.59	1.44	2.11	2.42	1.61	3.22	2.15	9
Centerville[2]	1.30[1]	1.78	3.81	2.25	2.28	2.11	2.64	4.11	1.56	2.54	9
Lamoni[2]	1.77[1]	0.99	5.03	1.42	3.07	2.13	1.34	2.94	3.42	2.54	9
Mt. Ayr[2]	2.44	2.95	3.17	1.53	3.32	--[6]	1.65	2.94	--[3]	2.57	8
Osceola[2]	2.06	1.35	4.26	2.33	4.30	4.15	3.34	3.33	1.83	2.99	9
Fairfield[2]	1.55	3.51	3.48	2.04	2.79	4.07	3.51	7.21	3.16	3.48	9

[1] Raw water not monitored and activated carbon treatment not used for this year. Raw water annual mean equals the finished water annual mean.

[2] Reported activated carbon treatment process in place.

[3] CWS not in Voluntary Monitoring Program.

[4] Raw water source not monitored. Finished water mean not substituted because Lake LaShane is not a direct water source.

[5] Raw water source not monitored. Finished water mean not substituted because activated carbon treatment in place.

[6] Data insufficient to calculate an annual mean.

Conclusions

The experience with atrazine in Iowa shows that label changes and improved management can reduce pesticide detection in water over a wide area, reducing the exposure of residents to atrazine in drinking water. It is clear that regulatory and educational efforts related to atrazine have improved water quality in Iowa. Atrazine detections and concentrations have declined in both surface and groundwater, as documented by many studies conducted throughout the state. Changes in precipitation alone do not explain atrazine trends. Table 5 shows annual precipitation departure from normal for Iowa for the years 1982-2002. A trend of decreasing rainfall might be expected to reduce atrazine leaching and runoff. However, rainfall in Iowa generally increased following drier than normal years in 1987-1989. Thus, declining atrazine concentrations cannot be explained by precipitation patterns.

Table 5. Precipitation departure from normal for Iowa: 1982-1999 (from Climatological Data for Iowa).

Year	Annual Rainfall Departure from Normal (in.)
1982	+8.67
1983	+3.40
1984	+4.05
1985	-1.52
1986	+7.20
1987	-0.04
1988	-11.46
1989	-8.61
1990	+6.37
1991	+4.86
1992	+3.55
1993	+15.11
1994	-3.03
1995	-0.44
1996	+0.93
1997	-3.27
1998	+7.37
1999	-0.32
2000	-2.68
2001	+2.23
2002	-3.14

30 year state average = 33.11 inches

Atrazine remains the most widely used herbicide in Iowa and the U.S., providing farmers with economical, effective weed control. Despite introduction of many new herbicides and herbicide-tolerant crops, atrazine remains popular with corn farmers. Atrazine at reduced rates is often included with newer herbicides either as a package-mix or tank-mix partner. Thus, while average atrazine application rates per acre have declined, more acres are treated today than in the past. In 1995, the last year a comprehensive pesticide use survey was conducted in Iowa, 67.2% of corn acreage was treated with atrazine. That compares to 32.9%, 49%, and 61% of acres treated with atrazine in 1979, 1985, and 1990, respectively. However, total pounds of atrazine applied in Iowa declined from 9.7 million lb in 1985 to 6.4 million lb in 1995 (Hartzler et al. 1997). The latest USDA National Agricultural Statistics Service pesticide use survey data (for the year 2002) show atrazine use on 60 percent of Iowa corn acres at an average rate of 0.94 lb ac^{-1} (USDA/ERS 2003).

Iowa farmers have recognized the importance of protecting water and have complied with label changes. A 1995 Iowa State University survey (Pope et al. 1997) confirmed that farmers have changed how they manage atrazine. Thirty-eight % of farmers reported reducing the rate of atrazine used per acre. Farmers were highly aware of setback requirements. Sixty-nine % responded that they had established application setbacks around streams, tile inlets, and wells. This is a high rate of response, considering that some farms would not have streams, tile inlets, or wells near fields. When asked about perceptions of atrazine management rules and label restrictions, 58% responded that current restrictions were OK, 23% that they were too restrictive, 18% were unsure, and less than 1% that they were not restrictive enough. Thus, most Iowa farmers view atrazine restrictions as tough, but necessary, and most are complying.

While atrazine detections and concentrations in Iowa ground and surface water have declined, protection efforts need to continue. Some surface water systems remain vulnerable to extreme weather events. Success of atrazine BMPs in Iowa indicates that similar approaches should be effective in other regions.

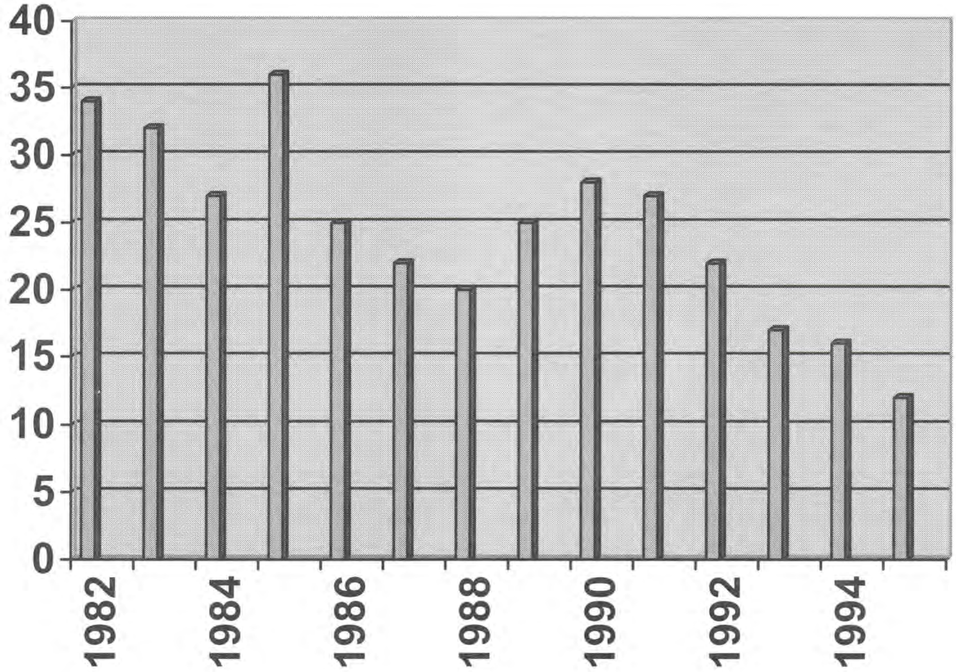

Figure 1. Atrazine detection rate in Iowa groundwater 1982-1995
(Skopec and Hoyer, Pesticide Trends in Surface and Groundwater in Iowa: 1980-1995, Iowa Dept. of Natural Resources)

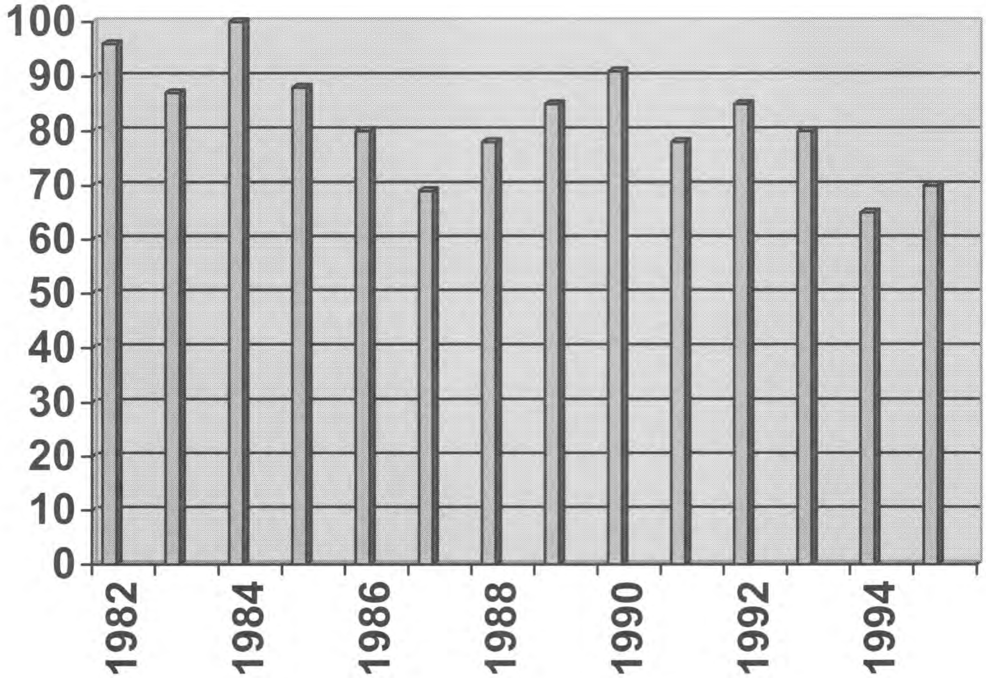

Figure 2. Atrazine detection rate in Iowa surface water: 1982-1995.
(Skopec and Hoyer, Pesticide Trends in Surface and Groundwater in Iowa: 1980-1995, Iowa Dept. of Natural Resources)

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